CLAIMS

1. A process for continuously forming thermoplastic products having precision microstructured surfaces thereon, comprising the steps of:

providing a continuous double band press having upper and lower primary bands, at least one of said bands being provided with a tool surface having the inverse topography of the precision microstructured surface to be formed;

continuously feeding a thermoplastic material through said press and between said bands;

heating said material to its embossing temperature Te;

applying sufficient pressure to said material to cause the precise engagement of said heated thermoplastic material with said belts;

applying pressure to said heated material through said belts and said tool surface to emboss the material with said precise microstructured pattern; and

cooling said material while maintaining pressure on said material, and while said material is moving through said press.

2. The method according to claim 1, in which the upper primary band is provided with said tool surface having the inverse topography of the structure to be formed.

3. The method according to claim 1, wherein said lower primary band is provided with said tool surface having the inverse topography of the precision microstructure to be formed.

4. The method according to claim 1, wherein each of said upper and lower bands is provided with a tool surface having the inverse topography of the precision microstructure surfaces to be formed.

5. The method according to claim 1, further comprising the step of providing an overlay band which is provided with said tool surface, said overlay band being positioned on one of the upper or lower primary bands.

6. The method according to claim 5, wherein said overlay band is positioned on said upper primary band.

7. The method according to claim 6, wherein said overlay band is positioned on said lower primary band.

8. The method according to claim 5, wherein an overlay band is positioned on each of said upper and lower primary bands.

9. The method according to claim 1, wherein at least some of said heating step is conducted prior to said material engaging said bands.

10. The method according to claim 1, wherein said heating step is at least partially conducted while said material is moving through said bands.

11. The process of claim 1, wherein said material is fed through said press at a rate of between about 21 (6.40) and about 32 (9.75) feet (meters) per minute.

12. The method according to claim 1, wherein during said heating step said material is brought to between the range of 250°F to 750°F (120°F to 399°C) and said pressure is about

150-1000 psi (1.03 MPa - 6.89 MPa).

13. The method according to claim 1, wherein the cooling temperature is in the range of between about 35°F to 75°F (2°C to 24°C).

14. The method according to claim 1, wherein said material consists of a plurality of thermoplastic materials.

15. An apparatus for continuously forming thermoplastic products having precision microstructured surfaces thereon, comprising:

a continuous double band press having upper and lower primary bands providing a relatively planar region therebetween, at least one of said bands being provided with a tool surface having the inverse topography of the precision microstructured surface to be formed;

means for continuously feeding a thermoplastic material through said press and between said bands;

means for heating said material to its embossing temperature T_e;

means for applying sufficient pressure to said belts to cause the precise engagement of said heated thermoplastic material with said belts and said tool surface to emboss said material with said precise microstructured pattern; and

means for cooling said material while maintaining pressure on said material, and while said material is moving through said press.

16. The apparatus according to claim 15, in which the upper primary band is provided with said tool surface having the inverse topography of the structure to be formed.

17. The apparatus according to claim 15, wherein said lower primary band is provided with said tool surface having the inverse topography of the precision microstructure to be formed.

18. The apparatus of claim 15, wherein each of said upper and lower bands is provided with a tool surface having the inverse topography of the precision microstructure surface to be formed.

19. The apparatus of claim 15, and wherein said tool surface is provided on an overlay band and said overlay band is positioned on one of said upper or lower primary bands.

20. The apparatus of claim 19, wherein said overlay band is positioned on said upper primary band.

21. The apparatus of claim 19, wherein said overlay band is positioned on said lower primary band.

22. The apparatus of claim 19, wherein an overlay band is positioned on each of said upper and lower primary bands.

23. The apparatus of claim 15, wherein said pressure producing means is provided a range of 250 to 1000 psi (1.72 MPa to 6.89 MPa).

24. The apparatus of claim 15, wherein said heating means is capable of heating said

material within a range of 250° to 750°F (121°C to 399°C).

25. The apparatus of claim 15, wherein said bands are operated such that said material is fed through said press at a rate of between about 21 (6.40) and about 32 (9.75) feet (meters) per minute.

26. The apparatus of claim 15, wherein said heating means combining said material to between the range of 250° to 580°F (121°C to 304°C) and said pressure is about 150-1000 psi (1.03 0 6.89 MPa).

27. The apparatus according to claim 15, wherein said cooling means is in the range of between about 35° to 75°F (2°C to 24°C).

28. A method of making an embossing tool for forming precise microstructure articles, comprising the steps of:

providing a substantially planar tool of a first material, said tool having first and second opposite ends;

providing a patterned side and a back side opposite the patterned side on said tool;

placing said opposite ends together so that the unpatterned side faces inwardly;

providing a second interfacing material between said opposite ends, said interface material being of a different material then said planar tool material; and

laser welding said opposite ends together via the interface material so that the opposing ends of the tool are fixedly joined and a continuous tool is formed.

29. The method of claim 28, wherein the step of welding the ends together comprises welding said first and second ends together with less than 100% penetration of the resulting weld.

30. The method of claim 29 wherein the depth of penetration of the resulting weld is between about 70-85% of the distance from the unpatterned surface and about 15-30% of the distance from the patterned surface.

31. The method of claim 30, wherein the depth of weld penetration from the unpatterned surface is about 83% of the tool thickness and the depth of weld penetration from the patterned surface is about 17% of the tool thickness.

32. The method of claim 28, wherein said first material is nickel and said second material is compatible with nickel and provides a weld of tensile strength greater than nickel to nickel.

33. A method of making a continuous flexible embossing tool for use in a continuous double band press, comprising the steps of:

assembling at least two segments of tooling each of a first composition and each segment having one end opposite one end of the adjacent segment;

each segment having a patterned side and a back side which when assembled, provide the patterned sides oriented in the same direction;

placing the opposing segment ends together and welding the ends together utilizing an interface material formed of a different material than the material of said segments, such that the opposing ends of the segments are joined.

34. The method of claim 33, further comprising the steps of assembling a series of said segments in accordance with the procedure set forth in claim 33 to form a cylindrical shape and wherein the patterned sides form the exterior of the cylinder.

35. The method of claim 28, wherein said interface material has a width of between 0.001 inches and 0.010" inches (25 microns to 254 microns).

36. The method of claim 28, wherein said interface material is about 0.030 inches (760 microns) thick.

37. The method of claim 28, wherein said belt is about 0.030 inches (760 microns) thick.

38. The method of claim 28, wherein said laser is pulsed for approximately 3.0 ms in duration.

39. A flexible endless metal belt for embossing precision microstructures, said belt having an outer surface provided with a topography which is the inverse of the precision microstructure product to be embossed thereby;

said belt being formed of a first material and having at least one weld extending across the width thereof, said weld comprising second interface material which is of a material different than said first material of which said belt is composed.

40. The tool of claim 39, wherein said first material is nickel and said interface material is stainless steel.

41. The tool of claim 39 wherein said tool has a tensile strength of about 71.8 kpsi (495 MPa).

42. The tool of claim 39 wherein said tool is made up of a plurality of segments welded together using interface material at each weld.

43. The tool of claim 39 wherein said interface material is between 0.001 inch and 0.010 inch (25 microns to 254 microns) wide.

44. The tool of claim 39, wherein said belt is about 0.030 inches (762 microns) thick.

45. The tool of claim 39, wherein the perimeter of said belt is between about 370 inches to 419 inches (0.94 meters to 1.06 meters).

46. The tool according to claim 39, wherein said microstructure pattern provided on said embossing tool includes at least a portion for forming an array of microcube elements.

47. The tool according to claim 39, wherein said microstructure pattern provided on said embossing tool includes at least a portion for forming a pattern of microfluidic channels.

48. The apparatus according to claim 39, wherein said microstructure pattern on said embossing tool includes at least a portion for forming an array of precise geometric recessed profiles, each recess having a flat bottom surface with a major dimension of about 0.04 inches (1000 microns) or less;

an upwardly tapered wall at an angle of between 10°-90° normal to the bottom;

a depth of between 0.000004 inches to 0.04 inches (0.10 microns to 1000 microns) and an upper opening between about 0.000004 inches to 0.04 inches (0.10 microns to 1000 microns) in major dimension.

49. The apparatus of claim 19, and further including tracking/steering means for said overlay band to keep said band in alignment with said primary band.